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**METHOD AND APPARATUS FOR DUAL HARDWARE AND SOFTWARE  
CRYPTOGRAPHY**

**BACKGROUND OF THE INVENTION**

5 **1. Technical Field:**

The present invention relates generally to an improved data processing system, and in particular to a method and apparatus for performing cryptography operations. Still more particularly, the present invention provides a method, apparatus, and computer implemented instructions for a dual hardware and software cryptography system.

**2. Description of Related Art:**

15 Cryptography is the art and science of keeping information secure. A person who does not know the method used to change the information to keep it secure cannot copy the method used or reverse the change. The basic components of cryptographic systems are used to encipher (scramble) information so that it is difficult to  
20 determine the meaning without the appropriate key or keys to decipher (unscramble) the information. The components include cryptographic algorithms (mathematical functions) for enciphering or deciphering information and keys  
25 (strings of information that cause a cryptographic algorithm to encipher or decipher in a distinctive way). Symmetric and asymmetric are two examples of cryptographic systems. Symmetric systems use the same key to encipher and decipher. This system is also referred to  
30 as a secret key algorithm.

In contrast, asymmetric systems generate and use

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different keys to encipher and decipher a secure key pair. With this key pair, consisting of a public key and a private key, only one key can decipher what the other enciphers. Asymmetric key pairs are used in creating  
5 digital signatures and transporting symmetric keys. In the past, most encryption systems only used symmetric cryptography. The problem with symmetric cryptography, however, is the difficulty encountered in distributing keys to targeted recipients. Since symmetric cryptography  
10 uses the same key for enciphering and deciphering, a person has to use creative and difficult means to prevent the unwanted from intercepting the key. If a third party were to intercept the key, they could use it to decipher anything it was used to encipher.

15 A solution to this problem is public key cryptography which uses asymmetric cryptography to transport symmetric keys. In such a system, a recipient's public key is used to encipher a symmetric key. Once enciphered, the symmetric key can only be easily  
20 deciphered using the corresponding private key.

The Internet and other networked environments are full of hackers, viruses, eavesdroppers, thieves, terrorists, and other threats to information privacy and control. Cryptography is necessary because it helps  
25 individuals and organizations protect themselves from these threats. For years, cryptography has been predominantly used by government intelligence agencies, military forces, and the banking industry. Today, others are beginning to realize the benefits and the necessity  
30 of cryptography.

Cryptographic systems may be implanted using

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hardware. As an overview summary, hardware cryptography implementation is required in certain industrial sectors such as financial areas. It is important that confidential information is kept in secure location. A classic example is the storage of private key. Although the access to the private key can be limited by the data structure/nature in software (e.g. declaring the key as a private attribute which cannot be accessed by any outside application), the memory that stores the key is not protected by secure means. An intruder/adversary can read the key information by brutal memory reading or any work around. Besides secure storage, hardware also provides an environment to execute operations that involve confidential data such as digital signature and encryption. Hardware provides a secure means for storing confidential data and executing sensitive operations.

Cryptographic systems also may be implemented in software. In this type of implementation, the speed of a software implemented operation depends solely on the operating machine. The performance of software implementation can be improved by various techniques such as multithreading. The execution time is not necessary proportional to the size of input data once the code is loaded to memory since no more Input/Output (I/O) is needed and thus repetitive operation would yield in smaller overhead and shorter execution time.

Hardware, on the other hand, due to extra connections to the operating machine and limited memory (relatively smaller to the operating machine), has a limited and costly performance.

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## SUMMARY OF THE INVENTION

The present invention provides a method, apparatus, and computer implemented instructions for executing cryptographic operations in a single architecture that embraces the advantages of both software and hardware implementations. Responsive to a request to perform a cryptographic operation, one of a software process and a hardware process is selected (whether specified by the application or picked by the architecture according to some policy) for performing the cryptographic operation based on a policy which process results in an available resources to perform the cryptographic operation to form a selected process which will yield an optimal performance. The cryptographic operation is performed using the selected process.

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### BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

**Figure 1** is a pictorial representation of a data processing system in which the present invention may be implemented in accordance with a preferred embodiment of the present invention;

**Figure 2** is a block diagram of a data processing system in which the present invention may be implemented;

**Figure 3** is a diagram of a dual hardware and software cryptography in accordance with a preferred embodiment of the present invention;

**Figure 4** is a flowchart of a process used for processing requests for cryptographic operations in accordance with a preferred embodiment of the present invention;

**Figure 5** is a flowchart of a process used for processing a request for a digital signed signature in accordance with a preferred embodiment of the present invention; and

**Figure 6** is a flowchart of a process used for processing a request from an application in accordance with a preferred embodiment of the present invention.

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### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference now to the figures and in particular  
5 with reference to **Figure 1**, a pictorial representation of  
a data processing system in which the present invention  
may be implemented is depicted in accordance with a  
preferred embodiment of the present invention. A  
computer **100** is depicted which includes a system unit  
10 **110**, a video display terminal **102**, a keyboard **104**,  
storage devices **108**, which may include floppy drives and  
other types of permanent and removable storage media, and  
mouse **106**. Additional input devices may be included with  
personal computer **100**, such as, for example, a joystick,  
15 touchpad, touch screen, trackball, microphone, and the  
like. Computer **100** can be implemented using any suitable  
computer, such as an IBM RS/6000 computer or  
IntelliStation computer, which are products of  
International Business Machines Corporation, located in  
20 Armonk, New York. Although the depicted representation  
shows a computer, other embodiments of the present  
invention may be implemented in other types of data  
processing systems, such as a network computer. Computer  
**100** also preferably includes a graphical user interface  
25 that may be implemented by means of systems software  
residing in computer readable media in operation within  
computer **100**.

With reference now to **Figure 2**, a block diagram of a  
data processing system is shown in which the present  
30 invention may be implemented. Data processing system **200**

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is an example of a computer, such as computer **100** in **Figure 1**, in which code or instructions implementing the processes of the present invention may be located. Data processing system **200** employs a peripheral component

5 interconnect (PCI) local bus architecture. Although the depicted example employs a PCI bus, other bus architectures such as Accelerated Graphics Port (AGP) and Industry Standard Architecture (ISA) may be used. Processor **202** and main memory **204** are connected to PCI

10 local bus **206** through PCI bridge **208**. PCI bridge **208** also may include an integrated memory controller and cache memory for processor **202**. Additional connections to PCI local bus **206** may be made through direct component interconnection or through add-in boards. In the depicted

15 example, local area network (LAN) adapter **210**, small computer system interface SCSI host bus adapter **212**, and expansion bus interface **214** are connected to PCI local bus **206** by direct component connection. In contrast, audio adapter **216**, graphics adapter **218**, and cryptographic

20 hardware **219** are connected to PCI local bus **206** by add-in boards inserted into expansion slots. Cryptographic hardware **219** provides cryptographic processes, such as cryptographic algorithms for processing data. For example, cryptographic hardware **219** may be used to encrypt data,

25 decrypt data, and generate digital signatures.

Expansion bus interface **214** provides a connection for a keyboard and mouse adapter **220**, modem **222**, and additional memory **224**. SCSI host bus adapter **212** provides a connection for hard disk drive **226**, tape drive **228**, and

30 CD-ROM drive **230**. Typical PCI local bus implementations

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will support three or four PCI expansion slots or add-in connectors.

An operating system runs on processor **202** and is used to coordinate and provide control of various components within data processing system **200** in **Figure 2**. The operating system may be a commercially available operating system such as Windows 2000, which is available from Microsoft Corporation. An object oriented programming system such as Java may run in conjunction with the operating system and provides calls to the operating system from Java programs or applications executing on data processing system **200**. "Java" is a trademark of Sun Microsystems, Inc. Instructions for the operating system, the object-oriented programming system, and applications or programs are located on storage devices, such as hard disk drive **226**, and may be loaded into main memory **204** for execution by processor **202**.

Those of ordinary skill in the art will appreciate that the hardware in **Figure 2** may vary depending on the implementation. Other internal hardware or peripheral devices, such as flash ROM (or equivalent nonvolatile memory) or optical disk drives and the like, may be used in addition to or in place of the hardware depicted in **Figure 2**. Also, the processes of the present invention may be applied to a multiprocessor data processing system.

For example, data processing system **200**, if optionally configured as a network computer, may not include SCSI host bus adapter **212**, hard disk drive **226**, tape drive **228**, and CD-ROM **230**, as noted by dotted line **232** in **Figure 2** denoting optional inclusion. In that



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case, the computer, to be properly called a client computer, must include some type of network communication interface, such as LAN adapter **210**, modem **222**, or the like. As another example, data processing system **200** may  
5 be a stand-alone system configured to be bootable without relying on some type of network communication interface, whether or not data processing system **200** comprises some type of network communication interface. As a further example, data processing system **200** may be a personal  
10 digital assistant (PDA), which is configured with ROM and/or flash ROM to provide non-volatile memory for storing operating system files and/or user-generated data.

The depicted example in **Figure 2** and above-described  
15 examples are not meant to imply architectural limitations. For example, data processing system **200** also may be a notebook computer or hand held computer in addition to taking the form of a PDA. Data processing system **200** also may be a kiosk or a Web appliance.

20 The processes of the present invention are performed by processor **202** using computer implemented instructions, which may be located in a memory such as, for example, main memory **204**, memory **224**, or in one or more peripheral devices **226-230**.

25 The present invention provides a method, apparatus, and computer implemented instructions for dual hardware and software cryptography. Disclosed is an architecture for dual hardware and software cryptography. Cryptography algorithms (public/private key, message digest, message  
30 authentication code) have been implemented through various vendors on different hardware and software.

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However, the effectiveness of these solutions has been limited by the forms of the implementation. The throughput of an algorithm is bounded by the availability on the hardware implementation while the security level (data is vulnerable in memory) is lowered by the software implementation. The present invention provides a secure and yet efficient and flexible architecture to utilize both hardware and software functionalities while minimizes the weakness of hardware and software cryptography implementations.

Turning now to **Figure 3**, a diagram of a dual hardware and software cryptography system is depicted in accordance with a preferred embodiment of the present invention. In this example, application **300** may send requests for cryptographic operations to cryptography system **302**, which includes an application programming interface (API) **304**, a policy engine **306**, a hardware cryptographic process **308**, a software cryptographic process **310**, and a conversion engine **312**.

API interface **304** provides a common interface for applications requiring cryptographic operations. Through API interface **304** allows application to make calls or send requests for cryptographic operations without requiring application to format these calls or requests a particular process within cryptographic systems **302**.

Thus, if different hardware and software processes are implemented for hardware cryptographic process **308** and software cryptographic process **310**, applications are not required to make different calls and request for each particular process. API interface **304** translates the request or call from an application, such as, application

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300, into the appropriate format for a particular cryptographic process within cryptographic system **302**.

Hardware cryptographic process **308** and software cryptographic process **310** represent hardware and software implementations of cryptographic algorithms. For example, these algorithms may include encryption algorithms used to encrypt data and create digital signatures. For example, public key algorithms may be implemented in both hardware and software form.

Public-key algorithms are complex mathematical equations using very large numbers. In practice, these algorithms are typically used only at critical points, such as for exchanging a symmetric key between entities or for signing a hash of a message (a hash is a fixed-size result obtained by applying a one-way mathematical function, called a hash algorithm, to data).

Using other forms of cryptography, such as symmetric-key cryptography, in combination with public-key cryptography optimizes performance. Public-key encryption provides an efficient method to send someone the secret key that was used when a symmetric encryption operation was performed on a large amount of data. Digital signatures may be produced by combining public-key encryption with hash algorithms to produce a digital signature. A hash is also referred to as a message digest. A hash is the conversion of a piece of data of any length into a non-reversible-fixed length number by applying a one way mathematical function called a hash algorithm to the data.

Hardware cryptographic process **308** and software cryptographic process **310** may be implemented using any of

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the known algorithms, such as, for example, Rivest-Shamir-Adleman (RSA) cryptographic algorithms, Digital Signature Algorithm (DSA), and Diffie-Helman Cryptographic algorithms.

5 Policy engine **306** is used to identify whether hardware cryptographic process **308** or software cryptographic process **310** will be used to perform the cryptographic operation. Policy engine **306** may make this decision in many different ways, depending on the  
10 particular implementation. In the depicted examples, application **300** may select whether hardware cryptographic process **306** or software cryptographic process **310** is to be used.

If, however, no particular type of process is  
15 requested by application **300**, policy engine **300** may select the particular type of process using a predefined set of rules. For example, policy engine **306** may include rules that select the particular process based on available resources in the data processing system. The  
20 rules may select the process, which uses the least amount of available resources or particular resources. The particular process may also be selected based on the process that provides the fastest processing. The set of rules may leverage the workload of the hardware/software.  
25 For example, if hardware is in use by another application, software will be used, and this rule will be a predefined dominant factor. An example of another rule is if the service is encryption, only hardware implementation is used. This type of rule is performance  
30 oriented to provide the fastest implementation. Further, in these examples, policy engine **306** is not statically

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configured. An application can configure policy engine  
**306** dynamically as desired. Different applications can  
concurrently run on this architecture with different  
configurations. It is up to the application whether it  
5 wants to dynamically change the configuration or  
predefine the usage of each algorithm services.

Conversion engine **312** is employed to translate  
objects, such as keys into the appropriate form for use.  
Since the representations of objects are different in  
10 software and hardware, cryptography system **302** through  
conversion engine **312** provides the necessary conversion  
of objects from software to hardware representations.  
Take the example of key representation. In software, the  
actual key values are stored in the key object and can be  
15 referenced by applications. In hardware, since the keys  
are kept in the hardware (and maybe referenced by some  
labels or tags), applications are prohibited from  
accessing the actual key values.

Without the conversion from one form to another,  
20 limits are present between the interoperability of the  
software and hardware processes. With conversion engine  
**312**, keys (and any other object) may be converted from  
one form to another form. Therefore, if cryptography  
system **302** realizes that a software object is  
25 interoperating with a hardware object, conversion engine  
**312** will convert an object from one form to another form  
so that interoperability within the architecture is  
preserved.

In this example, the software form of an object,  
30 such as a key, can be inserted to the hardware storage  
and is given/provided tags to reference it.

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Alternatively, in this storage the hardware key can be retrieved from the hardware storage and has the key values stored in the software representation. Existing software implementations can use conversion engine **312** to  
5 port the software keys to hardware and use a more secure key storage. If hardware implemented application prefers performance and cost over security, the hardware objects can be converted to software representation by using conversion engine **312** and achieve better performance by  
10 using purely software.

Turning next to **Figure 4**, a flowchart of a process used for processing requests for cryptographic operations is depicted in accordance with a preferred embodiment of the present invention. The processes illustrated in  
15 **Figure 4** may be implemented in a cryptography system or apparatus, such as, cryptography system **302** in **Figure 3**. The process begins by receiving a request for a cryptographic operation (step **400**). The request in this example is received using an API interface, such as API  
20 interface **304** in **Figure 3**. The request is then compared or examined with a policy (step **402**). The policy is a set of rules governing how a cryptographic operation will be performed. The request may specify a particular type of process may be used. In such a case, the policy may allow  
25 this specification how the cryptographic operation is to be performed. Alternatively, the policy may disallow a specification of a particular process and select the process based on other factors, such as available resources and speed of completion.

30 Next, a determination is made as to whether a software cryptographic process is to be used (step **404**).

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If a software cryptographic process is to be used, then objects are converted as needed (step **406**). This step may be performed by a conversion engine, such as conversion engine **312** in **Figure 3**. The cryptographic operation is then performed using the software cryptographic process (step **408**) with the process terminating thereafter.

Turning back to step **404**, if a software cryptographic process is not to be used, then objects are converted as needed for the hardware cryptographic process (step **410**).

10 The cryptographic operation is then performed using the hardware cryptographic process (step **412**) with the process terminating thereafter.

With reference now to **Figure 5**, a flowchart of a process used for processing a request for a digital signed signature is depicted in accordance with a preferred embodiment of the present invention. The process illustrated in **Figure 5** is a more detailed example of the processing of the request by cryptography system **302**.

20 The process begins by receiving a digital signing request (step **500**). A determination is made as to whether the policy specifies using software process for this request (step **502**). If the policy specifies using software, then a determination is made as to whether the input key is a software key (step **504**). If the input key is not software key, a conversion engine is used to convert the hardware key into a software key (step **506**). Then, the digital signing operation is carried out using the software key and a software cryptographic process (step **508**). A digitally signed signature is then returned

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to the requestor (step **510**) with the process terminating thereafter.

With reference again to step **504**, if the input key is a software key, the process proceeds directly to step  
5 **508**, skipping the conversion step.

Turning back to step **502**, if the policy does not specify the use of a software process, a determination is made as to whether the input key is a hardware key (step **512**). If the input key is not hardware key, a conversion  
10 engine is used to convert the software key into a hardware key (step **514**). Then, the digital signing operation is carried out using the hardware key and a hardware cryptographic process (step **516**) with the process then proceeding to step **510** as described above.

With reference now to **Figure 6**, a flowchart of a process used for processing a request from an application is depicted in accordance with a preferred embodiment of the present invention. The process illustrated in **Figure**  
15 **6** is used to identify whether more than one cryptographic operation is to be performed and to handle the performance of each identified operation.  
20

The process begins by receiving a request (step **600**). Thereafter, one or more cryptographic operation are identified by the request (step **602**). The mechanism of  
25 the present invention allows for breaking down a request into different cryptographic operations and selecting the type of cryptographic processes best for each operation based on a policy. Many of the cryptographic algorithms are a combination of several cryptographic algorithms.  
30 For instance, digital signature composes of message



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digest and public private key encryption. Less sensitive operations such as message digest may be performed by the faster implementation, software, while the more sensitive operation, encryption, may be performed by the more  
5 secure hardware.

Next, each identified cryptographic operation is then performed or processed (step **604**). The processing of the cryptographic operation in step **604** may be implemented by using a process described in **Figure 3**. The  
10 result is then returned to the originator of the request (step **606**) with the process terminating thereafter.

Thus, the present invention provides a method, apparatus, and computer implemented instructions for a secure and yet well performing cryptography  
15 implementation. The mechanism of the present invention combines the advantages of both hardware and software implementations and provides a flexible and configurable cryptography implementation. This mechanism utilizes the advantages of the two kinds of cryptographic  
20 implementations, hardware and software, to complement each other.

Besides utilization of the software and hardware features, this mechanism also provides a flexible means for the users to determine the usage of each kind  
25 service. An application that does not require hardware implementation can configure the mechanism to provide software implemented services only through a policy engine. Another application that exclusively requires hardware services can specify that only hardware services  
30 are desired.

From the user/application point of view, the usage

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of the services are the same since the API interface are the same for both software and hardware implementations. However, the ability to configure the usage of different forms of implementation greatly increases the performance  
5 and reduces the cost of cryptographic services. Less restricted operations are done by cheaper but faster software while sensitive operations are carried out by more secure hardware.

The performance of an operation using hardware or  
10 software may differ depending on a particular implementation. The performance also may depend on the size and nature of the operating data. For example, if the input data is small, hardware may provide a better performance than software. If the input data is large,  
15 since the operation code is already loaded to memory (overhead is the same for any data size), software provides better performance. The overhead in hardware in this case is proportional to the data size.

It is important to note that while the present  
20 invention has been described in the context of a fully functioning data processing system, those of ordinary skill in the art will appreciate that the processes of the present invention are capable of being distributed in the form of a computer readable medium of instructions  
25 and a variety of forms and that the present invention applies equally regardless of the particular type of signal bearing media actually used to carry out the distribution. Examples of computer readable media include recordable-type media, such as a floppy disk, a  
30 hard disk drive, a RAM, CD-ROMs, DVD-ROMs, and transmission-type media, such as digital and analog

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communications links, wired or wireless communications  
links using transmission forms, such as, for example,  
radio frequency and light wave transmissions. The  
computer readable media may take the form of coded  
5 formats that are decoded for actual use in a particular  
data processing system.

The description of the present invention has been  
presented for purposes of illustration and description,  
and is not intended to be exhaustive or limited to the  
10 invention in the form disclosed. Many modifications and  
variations will be apparent to those of ordinary skill in  
the art. The embodiment was chosen and described in  
order to best explain the principles of the invention,  
the practical application, and to enable others of  
15 ordinary skill in the art to understand the invention for  
various embodiments with various modifications as are  
suited to the particular use contemplated.